State of Oregon
Department of
Environmental
Quality

Briefing Paper:
What are "Conversion Technologies"?

November 2011

Primary Author: Bob Barrows

What are conversion technologies?

The term "conversion technology" encompasses a broad range of technologies used to convert solid waste into useful products, chemicals and fuels. Conversion technology facilities represent the next evolutionary step of solid waste material recovery systems, diverting organic (carbon- containing) solid wastes from the traditional disposal activities of landfilling and Municipal Solid Waste combustion. For the purposes of this paper direct combustion of solid waste, using heat to create electricity (sometimes called "waste-to-energy"), is not considered a conversion technology.

Conversion technology facilities convert energy stored in organic wastes to chemicals and products which can be used to create energy or make new products. Typical, separated solid wastes used for conversion include: manures; food wastes (industrial, commercial and residentially generated); fats, oils and greases; butcher wastes; waste plastics and waste tires. Some CT-generated products and chemicals include: 1) liquid fuels such as biodiesel, ethanol and oil; 2) electricity, heat and steam from combustible gases such as methane; 3) chemicals and consumer products from oils and synthetic gases ("syngases"); and 4) activated carbon for the food processing industry.

Conversion technology facilities can use a number of process technologies, including: anaerobic digestion, gasification, pyrolysis, thermal depolymerization and transesterification. These technologies can be defined by three types of conversion pathways or processes: 1) biochemical, 2) thermochemical and 3) physiochemical. All three pathways use or demonstrate using separated organic solid wastes (sometimes in combinations with industrial or petroleum refining residues).

Biochemical conversion

Biochemical conversion processes include anaerobic digestion (which occurs in controlled reactors or digesters and also in a less controlled environment in landfills), and anaerobic fermentation (for example, the conversion of sugars from cellulose to ethanol.) Biochemical conversion proceeds at lower temperatures and lower reaction rates than other conversion processes. Higher moisture feedstocks are generally good candidates for biochemical processes. The lignin fraction of biomass cannot be converted by anaerobic biochemical means and only very slowly through aerobic decomposition. As a consequence, a significant fraction of woody and some other fibrous feedstocks exits biochemical conversion as a residue. This residue, called digestate, may or may not have market value, although it can be composted.

Thermochemical conversion

Thermochemical conversion processes include gasification (conversion under high temperature and pressure in a low-oxygen environment to produce fuel gases) and pyrolysis (similar conversion to gasification but in the absence of oxygen) and thermal depolymerization (similar to pyrolysis, in the absence of oxygen, but in the presence of water). Thermochemical conversion is characterized by higher temperatures and faster conversion rates. It is best suited for lower moisture feedstocks. Thermochemical routes can convert the entire organic (carbon) portion of suitable feedstocks. The inorganic fraction (ash) of a feedstock does not contribute to the energy products but may contribute to fouling of high-temperature equipment, increased nutrient loading in wastewater treatment and disposal facilities, and in some cases by providing marketable coproducts or adding disposal cost. Inorganic constituents may also accelerate some of the conversion reactions. Plasma arc technology is a heating method that can be used in both pyrolysis and gasification systems. This method uses very high temperatures to break down the feedstock into elemental byproducts.

Physiochemical conversion

Physiochemical conversion processes include transesterification (biodiesel production) and involve the physical and chemical synthesis of products from feedstocks. It is primarily associated with the transformation of fresh or used vegetable oils, animal fats, greases, tallow and other suitable feedstocks into liquid fuels or biodiesel.

History of conversion technology

Anaerobic digestion is by far the most mature conversion technology, with thousands of commercial digesters operating in Europe alone, but also on most continents. In the U.S., dozens of anaerobic digesters are operating on dairy farms, but currently no digesters use municipal solid waste as a primary feedstock.

Pyrolysis and gasification technology has not progressed into commercial production to the extent of anaerobic digestion. Dozens of commercial-scale pyrolysis and gasification units are operating in Japan, with a couple each in Germany and one in the UK. However, in the US, these technologies have been slower to progress beyond bench scale to commercial production, with only a few promising projects progressing in California and Oregon.

In recent years an increasing number of CT facilities have been proposed for operation in Oregon, with a handful now operating. Table 1 lists facilities currently operating in Oregon and facilities that are planned and expected to be constructed and operated in the near future. Anaerobic digestion facilities account for 75 percent of CT facilities planned or currently operating in Oregon.

Table 1. Conversion Technology Facilities in Oregon, October 2011

Type of CT Facility	Status	Number
Anaerobic Digesters	**Operating**	
	Feedstock – manures; crop wastes; food processing wastes	5
	Planned or Under Construction	
	Feedstocks – manures; fats-oils-greases, crop wastes, various food wastes	10
Pyrolysis	**Operating**	
	Feedstock – waste plastics	1
	Feedstock - waste tires	1
	Planned	
	Feedstock – waste plastics	2
PlasmaArc Gasification	**Constructed, not operating**	
	Feedstock - mixed solid waste	1
Biodiesel Production	**Operating**	
	Feedstock – fats/oils/greases	> 5

Environmental and Other Benefits

Products and benefits from conversion technologies will differ based on the technology used and the feedstock converted. The following discusses products and benefits derived by type of conversion process.

Biochemical conversion

Biochemical conversion processes such as anaerobic digestion and anaerobic fermentation create combustible gases for electricity generation and/or liquid fuels. This displaces the use of fossil fuels. Process solids (digestate) can be used for various applications, including as livestock bedding and as composting facility feedstock. Since feedstocks tend to be wet, diversion of feedstocks to anaerobic digesters or fermenters can also provide the following benefits:

- helps avoid potential water quality impacts from traditional waste management when water is discharged from a leachate lagoon or solid waste transfer station
- reduces greenhouse gas emissions associated with methane generation from decomposition in landfills.

Thermochemical conversion

Thermochemical conversion processes such as gasification, pyrolysis and thermal depolymerization can remove materials from the solid waste stream and can also create: 1) <u>liquid fuels</u> such as biodiesel, ethanol and oil; 2) <u>electricity, heat and steam</u> from combustible gases such as methane; 3) <u>chemicals and consumer products</u> from oils and syngases; and 4) <u>activated carbon</u> for the food processing industry.

Physiochemical conversion

Physiochemical conversion processes such as transesterification can remove difficult-to-manage wastes from the solid waste stream, including waste fats, oils and greases as well as butcher waste and animal carcasses. Products derived by this process include liquid fuels and biodiesel, which can displace fossil fuels. Since feedstocks tend to be wet, use in biodiesel production facilities can provide additional benefits similar to biochemical conversion (reducing water quality impacts from traditional waste management and reducing greenhouse gas emissions from landfills).

Evaluating conversion technologies through different lenses

The benefits of conversion technologies depend on the looking glass "lens" through which one views the technology. From a material recovery perspective, conversion technology facilities recover materials that previously were destined for disposal, and can create valuable products, chemicals and energy. CT facilities reduce the amount of waste disposed in landfills and in waste-to-energy facilities.

Viewed through the "valued-added" lens, CT facilities can create feedstocks for new chemicals, new fuels or electrical production from wastes destined for landfill. Environmental benefits could be realized by using waste materials as feedstocks and avoiding the extraction of non-renewable fossil-fuel resources such as coal, crude oil and natural gas.

Viewed through a lens of energy and emissions, most CTs perform better than waste-to-energy and landfilling in several ways. The following are seen as benefits of conversion technologies when compared against landfilling and WTE (*New and Emerging Conversion Technologies - Report to the Legislature*, June 2007, commissioned by the California Integrated Waste Management Board).

- Conversion technologies produce more energy than landfilling and WTE. This creates life cycle benefits such as less dependence on non-renewable fuels such as natural gas.

- There are lower emissions of criteria air pollutants (nitrogen oxides and sulfur oxides) from conversion technologies than from landfilling and WTE.
- There are lower emissions of CO2 from conversion technologies than from landfilling and WTE. This is important from a climate change perspective.[1]
- Conversion technologies would decrease the amount of waste disposed in landfills.

However, this same report noted that:

- Limited data is available to adequately assess the impacts of dioxins, furans, and other hazardous air pollutants.
- The environmental benefits of the hypothetical conversion technology scenario are highly dependent upon their ability to achieve high conversion efficiencies and high materials recycling rates.

Issues and Concerns

Conversion technologies promise a number of benefits when compared to landfilling and waste-to-energy. However, when life cycle analysis is used to compare conversion technologies against waste reduction, recycling and composting, concerns about the use of CT facilities arise.

In *Assessment of Materials Management Options for the Massachusetts Solid Waste Management Plan Review, Final Report* (December 2008), the Tellus Institute makes the following findings after comparing waste reduction, recycling, composting, anaerobic digestion, pyrolysis, gasification, WTE and landfilling. The findings are grouped below with issues identified.

Findings:

1. From a lifecycle environmental emissions and energy perspective, source reduction, recycling and composting are the most advantageous management options for all (recyclable/compostable) materials in the waste stream.
2. From a life-cycle net energy perspective, compared to landfilling, WTE, anaerobic digestion, pyrolysis and gasification, recycling provides the most benefit by far, saving an estimated 2,250 kilowatt hours per ton of solid waste. Of the other waste management technologies, gasification and pyrolysis facilities have the most potential for energy production at about 660 kWh per ton, followed by modern waste to energy incinerators at 585 kWh per ton, and then anaerobic digestion, and landfilling.

Issue: Recyclable materials could be diverted from recycling to CT facilities, negating the significant environmental advantage of recycling that material.

Findings:

3. Carbon reductions per ton of MSW are two and a half times greater from modern landfills with efficient gas capture systems than from gasification and pyrolysis facilities.
4. Because it releases bound carbon in materials such as plastics, thermal conversion of certain materials to fuels or energy is problematic from a climate change perspective even at the potentially high-energy recovery levels of advanced conversion technologies.

[1] While California concluded that conversion technologies produce fewer CO_2 emissions than landfilling or WTE, subsequent evaluation by the Tellus Institute (see below) and Oregon DEQ has shown that this isn't necessarily the case in all circumstances. For example, in Oregon's case, landfilling of waste plastics may result in slightly lower greenhouse gas emissions than converting the waste plastics to synthetic crude using pyrolysis.

Issue: Landfills can act as carbon sinks by storing biologically-derived carbon in solid wastes like wood and yard debris. Landfills can also store fossil-derived carbon in solid wastes such as plastic and rubber. Thermal conversion can release bound carbon and increase concentrations of carbon dioxide in the atmosphere. Some conversion technologies present an odd case of trade-offs, where the production of alternative fuels don't necessarily reduce greenhouse gas emissions when compared to landfilling.

Findings:

5. No operating conversion technology facilities exist in the U.S. for municipal solid waste. Therefore, the environmental performance findings in the Tellus study are based largely on modeling and/or vendor claims as opposed to actual operating data.
6. When looking at human health and other environmental emission categories (beyond carbon dioxide equivalents), gasification/pyrolysis facilities are lower than WTE for all pollutants and lower than landfill emissions for all categories, except carbon dioxide.
7. Capital requirements for building conversion technology facilities and their likely need for long-term contracts to ensure an adequate feedstock waste stream may limit future flexibility of materials management efforts.

Issue: Given the lack of experience in the United States with conversion technology facilities and the expense of building them, conversion technologies for solid waste carry higher uncertainty and risk. While conversion technology facilities can fulfill needs in the current waste recovery infrastructure, locking in the use of waste for energy production may create barriers to expanded recycling or composting in the future, thereby negating the greater environmental benefit from recycling or composting.